

**Fish Species Assemblage Structure
in Ontario's Lakes**

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FISH SPECIES ASSEMBLAGE STRUCTURE IN ONTARIO'S LAKES

by

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ABSTRACT

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The fish species associations found in Ontario's lakes are clustered using Ochiai's association index. A number of species groupings are identified. They tend to be dominated by large gamefish species (top predators). Attempts to discriminate lake types based on the fish assemblages were no more successful than attempts based on the presence/absence of top predators. The species groupings are consistent with the Ryder and Kerr concept of harmonic communities though incompleteness of fish species lists, especially small and uncommon species, prevented a finer discrimination of assemblages.

RESUME

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Les associations d'espèces de poissons des lacs de l'Ontario sont groupées selon l'indice d'association d'Ochiai. Un certain nombre de groupements d'espèces sont identifiés. Ils ont tendance à être dominés par des espèces de gros poissons-gibier (prédateurs supérieurs). Les tentatives en vue de séparer les espèces lacustres en fonction des assemblages de poissons n'ont pas été plus fructueuses que celles fondées sur la présence ou l'absence de prédateurs supérieurs. Les groupements d'espèces sont conformes au concept de Ryder et de Kerr relatif aux communautés harmoniques même si des lacunes au niveau des listes des espèces de poissons, notamment celles des petites espèces et des espèces rares, n'ont pas permis une discrimination plus fine des assemblages.

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INTRODUCTION

Currently, fisheries management is undergoing a shift from a population to a community-based approach (Loftus and Regier 1972). This shift is difficult, for a number of reasons:

- (1) most fishery biologists have been trained only in population concepts;
- (2) there are few practical tools available to the community manager which compare with the classical stock-recruitment concepts of population methods; and
- (3) it is not always clear what constitutes a fish community.

Ryder (1972) described the fish assemblages of oligotrophic glacial lakes in North America. Ryder and Kerr (1978) have proposed the concept of a continuum of salmonid, percid-esocid and centrarchid communities. This continuum corresponds loosely to a continuum of limnological conditions, best described as going from oligo- through meso- to eutrophic. These fish communities are considered to be co-evolved assemblages of species. Little quantitative evidence has been presented to support this concept.

The purpose of this report is to analyze the fish assemblage structure in a large sample of Ontario's inland lakes, and factors affecting fish distribution. The concept of Ryder and Kerr (1978) can be assessed in light of the results. A better understanding of the structure of fish assemblage in Ontario could be of use in a number of pressing problems. There is a need to identify fish species and fish assemblages most threatened by environmental stresses such as acidic deposition, lake level modifications, deforestation, and cultural development. Fishery managers need to organize their assessment efforts so the results are applicable to the array of fish assemblages present.

MATERIALS AND METHODS

Since 1968, the Ontario Ministry of Natural Resources (OMNR) has been carrying out standardized inventories of lakes throughout the province. As of July 1983, the computer database contained data on 8,867 lakes. The data include morphometric measures (including lake area, maximum and mean depth, shoreline length and elevation), limnological measures (including temperature and oxygen profiles, conductivity and secchi depth) and a fish species list. The fish species lists are not considered exhaustive. Since the early 1970s a concerted effort has been made in the inventory program to capture many of the smaller species including cyprinids and darters.

Overall, there have been biases in the selection of lakes towards large, non-headwater lakes (Minns 1984) and lakes which contained preferred gamefish species such as brook trout, lake trout, and walleye (Minns 1981).

The fish species associations were examined by hierarchical cluster analysis using Ochiai's index of association (Janson and Vegelius 1981):

$$Ro = \frac{C}{A \cdot B}$$

where

Ro	=	Ochiai's index
A	=	the number of occurrences of species a
B	=	the number of occurrences of species b
C	=	the number of co-occurrences of species a and b.

This index has similar qualities to Jaccard's index (Janson and Vegelius 1981), but the effects of large disparities in occurrence ($A \gg B$ or vice versa) are reduced; i.e., clusters should be less dependent on species frequencies.

Only fish species with greater than 20 occurrences ($N = 64$) were included in the analysis. The clustering procedure was performed using Ward's (1963) error sums-of-squares grouping criterion. The list of fish species considered is given in Appendix A, including common name, scientific name, and frequency of occurrence in the lake inventory database.

Stepwise discriminant analysis (SPSS) was used to look for combinations of factors separating various fish species assemblages. The variables used for this analysis included lake area (ha), maximum depth (m), mean depth (m), elevation above sea level (m), secchi depth (m), and conductivity (uS.cm^{-2}). These variables were selected because they were the most frequently available and had been found to be useful in earlier analyses (Johnson *et al.* 1977; Minns 1981).

RESULTS

The clustering of fish species association using Ochiai's index produced a series of species groupings (Fig. 1). At the 1.1 level on the clustering scale there are ten distinct clusters. At the 1.6 level, those clusters have assembled into three 'supercluster C'.

The species found in clusters 8, 9, and 10 (supercluster C) correspond almost exactly with the 'coolwater' percid community described by Ryder and Kerr (1978). Those authors also noted a mutually exclusive grouping of species associated with brook trout which corresponds to the most isolated grouping, cluster 1. They also described a centrarchid community which is dominated in Ontario by the widely introduced smallmouth bass. This community

corresponds to cluster 5 and to a lesser degree clusters 6 and 7 (i.e., supercluster B). Clusters 2, 3, and 4 do not have any clearly identified place in the Ryder and Kerr's scheme. However, cluster 3 consists in large part of fish species with some lotic habitat association (Scott and Crossman 1973).

The distribution of occurrences of the ten assemblages by secondary watershed explains in part the grouping clusters in superclusters (Table 1, Fig. 2). Smallmouth bass, a key member of cluster 5, has a distribution in Ontario largely as a result of extensive introductions especially alongside railways! Clusters 7 and 6 in the same supercluster B, are largely found in southern Ontario and the Lake of the Woods area (5P) respectively.

The most prevalent assemblages, cluster 9, 1, and 5, include those species which lake selection was biased towards - brook trout, smallmouth bass, lake trout and walleye. Stepwise discriminant analysis was performed for the presence/absence of members for each of the three clusters: 1 - brook trout, 5 - centrarchid, and 9 - salmonid-percid. Six variables were considered as discriminators: $\ln$ lake area, $\ln$ maximum depth (Z_m), $\ln$ mean depth (z), elevation, $\ln$ secchi depth and conductivity. The $\ln$ transformation was used for those variables with positively skewed frequency distributions.

The results of the stepwise discriminant analyses (Table 2) indicate the relative importance of the factors possibly affecting presence-absence. The brook trout assemblage (cluster 1) tends to be found in lakes with a smaller surface area at higher elevations. The centrarchid assemblage (cluster 5) tends to be found in lakes with greater mean depth, but less maximum depth, and lower elevations. The contrast of depth variables for this assemblage is indicative of lakes with a greater littoral development. The salmonid-percid

assemblage (cluster 9) tends to be found in larger lakes with a greater mean depth. In all three analyses, the discriminant functions were significant and the classification success significantly better than that expected by chance, using the test described by Titus et al. (1984).

These results should not be taken as evidence of a clear-cut detection of presence/absence. Stepwise discriminant analyses for the presence/absence of the top predators in the three clusters produced similar results (Table 3). Brook trout are found in small lakes at higher elevations; smallmouth bass are found in larger lakes with a greater littoral development; lake trout are found in deeper larger lakes; and walleye are found in larger shallower lakes with relative smaller secchi depths, i.e. more turbid waters. Classification success with single species presence/absence was as good as with the cluster presence/absence (Table 3).

DISCUSSION

As Tonn et al. (1983) pointed out, fishery management decisions are often made on a species by species basis with little reference to the structure of the fish assemblage of the lakes in question. These authors and others (Johnson et al., 1977; Harvey, 1978, 1981) have shown that it is possible to identify and discriminate among fish assemblage types using simple lake characteristics. The results attained here indicate there are three main assemblages each headed by one or more important game fish species.

The first group (A) is one of small lakes at higher elevations with a cluster led by brook trout being a discrete subgrouping. The second group (B) is one of larger lakes with relatively greater littoral development. Many

centrarchids, including smallmouth bass, are found in this group. Within Ontario, this group is mostly found in the St. Lawrence - Great Lakes drainage with a southerly concentration. The third group (C) which includes salmonids, percids and esocids, is one of larger deeper lakes with a more northerly extension of distribution. These groups are not necessarily mutually exclusive. Some lakes, especially larger ones, may have representatives of all three groups present.

The distributions of brook trout and smallmouth bass have been greatly extended by introductions. Despite this, there is evidence of some exclusion. The bias toward certain fish species will tend to overestimate their co-occurrence (Minns 1986). Johnson et al. (1977) found that northern pike (Esox lucius) (Group C) and smallmouth bass (Group B) combinations are relatively uncommon, especially in small lakes. Minns (1981) found that brook trout (Group A) are rarely found with northern pike or smallmouth bass in small lakes. Tonn et al. (1983) described the community types in a small (30) group of small (<100 ha) northern Wisconsin lakes. They were able to discriminate three types: an Umbra limi - cyprinid group, centrarchid lakes, and pike lakes. The cyprinid group include many species that belong to Group A here. Harvey (1981) reported on a survey of lakes in the Bruce Peninsula (in Watershed 2F, Fig. 2). He found that the presence/absence of northern pike strongly influenced the probability of finding four species of small fish - northern redbelly dace (Phoxinus eos), finescale dace (Phoxinus neogaeus), brook stickleback (Culea inconstans) and fathead minnow (Pimephales promelas). These four species are all members of the brook trout cluster (1) shown here. Northern pike and Brook trout rarely co-occur, suggesting that pike and the brook trout cluster members cannot co-exist.

Smaller scale surveys such as those of Harvey (1978, 1981) and Somers and Harvey (1984) can produce fish community patterns somewhat at variance with the picture obtained here with a very large Ontario wide sample. Harvey's (1978) survey of fish communities in Manitoulin Island lakes (Watershed 2C, Fig. 2) found brook trout strongly associated with rainbow trout (Salmo gairdneri) but not with the other members of its cluster (Fig. 1). The other members of cluster 1 were closely associated with the central mudminnow (Umbra limi) as found by Tonn et al. (1983). In the Bruce Peninsula, Harvey (1981) found the percoid and centrarchid groups were interspersed, co-occurring. The Manitoulin and Bruce Peninsula results reflect the more southerly location of the lakes. Further north near Wawa (Watershed 2B, Fig. 2), Somers and Harvey (1984) found fish species groupings that are largely similar to those presented here. Disparities between extensive and localized surveys are likely due to biogeographic effects and/or man's intervention. In small areas, the ecological determinants of presence/absence are likely to be more in evidence and biogeographic effects less evident.

The species groupings can be interpreted in biogeographical terms. The salmonid and percoid group (C) is considered typical of the north temperate freshwater habitats in North America (Ryder 1972; Ryder and Kerr 1978). They invaded the larger oligo/mesotrophic freshwaters of Ontario after the last glaciation from Mississippi and Upper Missouri refugia. This distribution pattern in Ontario complements that seen in adjoining Quebec (Legendre and Legendre 1984). The brook trout grouping (A) is the complement that invaded the small freshwater lakes and streams from an eastern refugium. The centrarchid group (B) represents the next harmonic point on the community spectrum of Ryder and Kerr (1978). The members of group B have an association

with warmer, somewhat more meso-/eutrophic lakes. Johnson et al. (1977) suggested that the climate patterns determined the northern limits of smallmouth bass success after introduction to areas accessible to man. Mixed among the clusters, there are a number of euryhaline species, such as alewife, rainbow smelt, and the ninespine stickleback which have gained access into Ontario's lakes via the St. Lawrence - Great Lakes river system.

Despite the use of Ochiai's index instead of the Jaccard index, the species clusters were strongly dependent on the species frequencies. The detection of smaller and numerically rare fish species was poor in the early stages (1960 to early 1970) of accumulation of the lake inventory data base. The main species groupings do not appear to be affected by this problem but it is likely that somewhat different groupings might have emerged if the species lists were complete. It is not clear from Ryder (1972) and Ryder and Kerr (1978) whether there are subgroupings of ecological significance within their scheme of harmonic communities. One possibility is that each harmonic community consists of subgroupings made up of sets of species of various sizes. For instance, cluster 9 which contained the largest and most frequently encountered species of larger and deeper lakes, might be dispersed into two or more groupings, each drawing additional members from clusters 8 and 10. A deepwater assemblage that would be consistent with the harmonic community concept might have lake trout and burbot (Lota lota) from cluster 9 with trout-perch and ninespine stickleback from cluster 8 and mottled and slimy sculpins (Cottus cognatus) from cluster 10.

Some of the patterns found here may be the result of extensive stocking of some top predators throughout Ontario. The distributions of brook trout and smallmouth bass were greatly expanded, the former largely via aerial

stocking and the latter largely in proximity to the railway lines across the province. Differences in stocking tactics could lead to distributional skews. The OMNR lake inventory does not presently include data on the stocking history of each inventoried lake. So correction for stocking biases is not possible at present. However many of the fish stocks resulting are now self-sustaining and environmental/climatic limitations on occurrence are evident (Johnson et al 1977). Changes in distribution while altering the frequencies of various species assemblages, need not of themselves alter lake by lake patterns of association.

Overall, the patterns of fish assemblages found here and elsewhere tend to support the ideas of Ryder and Kerr (1978). There is perhaps a danger in focussing on top predators, as suggested by Tonn et al. (1983). As the shift to assemblage-based fishery management proceeds there will be a greater need to determine the rules of assemblage formation. Barbour and Brown (1974) showed that lake size was a strong predictor of the number of fish species in a lake. The next stage will be to build on the approach developed here and advanced by others such as Harvey (1981) and Tonn et al. (1983).

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Table 1: Percent occurrence of assemblages by secondary watershed in Ontario.

Secondary ¹ watershed	Percentage Occurrence of Assemblage ²										Number
	1	2	3	4	5	6	7	8	9	10	
2A	44.5	0.6	21.6	2.6	16.5	-	-	19.9	81.5	35.0	357
2B	53.1	0.5	35.8	3.4	5.2	0.2	-	12.1	84.9	35.5	654
2C	51.2	2.4	45.0	4.5	36.1	1.2	2.9	5.7	84.3	19.3	803
2D	33.1	2.9	29.2	0.5	58.6	4.2	1.8	3.1	83.9	33.1	384
2E	39.8	4.4	40.4	1.4	76.8	3.8	3.0	3.8	84.0	20.6	792
2F	34.4	5.0	23.1	1.4	52.0	26.7	5.9	0.9	52.0	29.9	221
2G	14.3	15.4	15.4	2.2	58.2	6.6	16.5	1.1	40.7	2.2	91
2H	36.6	15.1	37.7	1.5	80.7	6.3	16.8	4.0	79.0	20.4	544
2J	43.8	0.8	26.3	0.3	31.9	2.3	0.5	4.7	83.1	19.1	598
2K	60.0	3.3	43.2	1.0	75.5	5.4	3.9	3.4	79.5	15.5	984
2L	25.9	1.9	20.4	1.9	87.0	42.6	70.4	9.3	87.0	44.4	54
2M	20.6	1.0	16.5	1.0	96.9	42.3	73.2	7.2	94.8	25.8	97
4A	53.3	-	66.7	-	-	-	-	93.3	100.0	86.7	15
4B	-	-	-	-	-	-	-	-	-	-	0
4C	48.0	1.3	32.0	-	1.3	-	-	70.7	100.0	93.3	75
4D	28.6	4.8	40.5	4.8	2.4	-	-	78.6	100.0	85.7	42
4E	33.3	-	83.3	-	-	-	-	83.3	100.0	50.0	6
4F	18.2	11.4	25.0	-	-	2.3	-	54.5	97.7	88.6	44
4G	18.0	6.3	40.2	0.5	14.3	-	-	54.0	97.9	92.1	189
4H	25.0	-	-	-	-	-	-	50.0	75.0	75.0	4
4J	40.4	0.3	18.3	0.3	1.7	0.3	-	12.6	76.7	39.3	356
4K	-	-	-	-	-	-	-	-	100.0	-	1
4L	30.5	0.3	15.7	0.2	11.8	-	-	6.0	80.2	45.9	636
4M	35.4	-	11.4	-	8.3	0.4	-	7.4	73.4	24.7	542
4N	9.1	9.1	6.1	-	12.1	-	-	33.3	97.0	60.6	33
5P	36.9	5.1	16.0	11.4	54.7	10.8	3.5	15.6	99.1	78.9	686
5Q	37.7	7.9	8.5	0.9	37.8	2.3	0.2	32.8	96.4	75.1	555
5R	37.5	-	2.8	-	16.7	-	1.4	48.6	98.6	91.7	72
Unknown ³	43.8	9.4	46.9	6.3	50.0	6.3	12.5	6.3	75.0	34.4	32
TOTAL	41.4	3.7	28.5	2.2	41.4	4.3	3.6	11.6	83.5	36.7	8867

¹ See Fig. 2 for location.

² Presence of one or more of species in numbered clusters in Fig. 1.

³ Watershed missing or wrong.

Table 2: Results of stepwise discriminant analysis for the presence/absence of each of the three most prevalent fish assemblages (clusters 1, 5, and 9).

Category	Fish assemblage		
	1 - Brook trout	5 - Centrarchid	9 - Salmonid-percid
<u>Sample size</u>			
# Without	3,800	3,672	875
# With	2,512	2,651	5,369
χ^2	727.0 ²	492.3 ²	1,791.3 ²
<u>Standardized discriminant</u>			
<u>Coefficients:</u>			
Loge area	0.926	n.e.	0.975
Loge Zm	-0.302	0.777	-0.363
Loge z	n.e.	-1.191	0.455
Elevation	-0.391	0.925	-0.232
Loge secchi	-0.248	n.e.	0.048
Conductivity	0.114	0.102	-0.050
<u>Centroids:</u>			
Without	0.287	0.243	-1.428
With	-0.430	-0.338	0.233
<u>Classification:</u>			
% Successful	64.8	59.9	79.7
% expected by chance	49.9	50.4	64.1
Kappa ¹	0.298	0.191	0.434
Z	23.68 ²	15.02 ²	25.65 ²

1 Titus *et al.* (1984).

2 Significant value at P=0.001.

n.e. Variable not entered in stepwise analysis.

Table 3: Results of stepwise discriminant analysis for the presence/absence of each of four important gamefish species.

Category	Brook trout	Smallmouth bass	Lake trout	Walleye
<u>Sample size:</u>				
# Without	5,199	5,160	5,096	4,437
# With	1,045	1,084	1,148	1,807
χ^2	933.3 ²	735.1 ²	2,181.2 ²	2,290.9 ²
<u>Standardized discriminant</u>				
<u>Coefficients:</u>				
Loge area	0.970	0.458	0.334	0.991
Loge Zm	-0.244	-0.524	n.e.	0.133
Loge z	n.e.	0.655	0.696	-0.210
Elevation	-0.377	-0.827	0.114	-0.102
Loge secchi	-0.200	0.473	0.283	-0.371
Conductivity	0.142	n.e.	n.e.	0.084
<u>Centroids:</u>				
Without	0.180	-0.162	-0.307	-0.425
With	-0.896	0.771	1.363	1.044
<u>Classification:</u>				
% successful	69.9	67.6	80.3	77.4
% expected by chance	57.1	57.0	59.9	54.9
Kappa	0.298	0.246	0.508	0.497
Z	20.38 ²	16.90 ²	32.90 ²	35.60 ²

(See Table 2 for explanation of 1 and 2).

n.e. Not entered in analysis

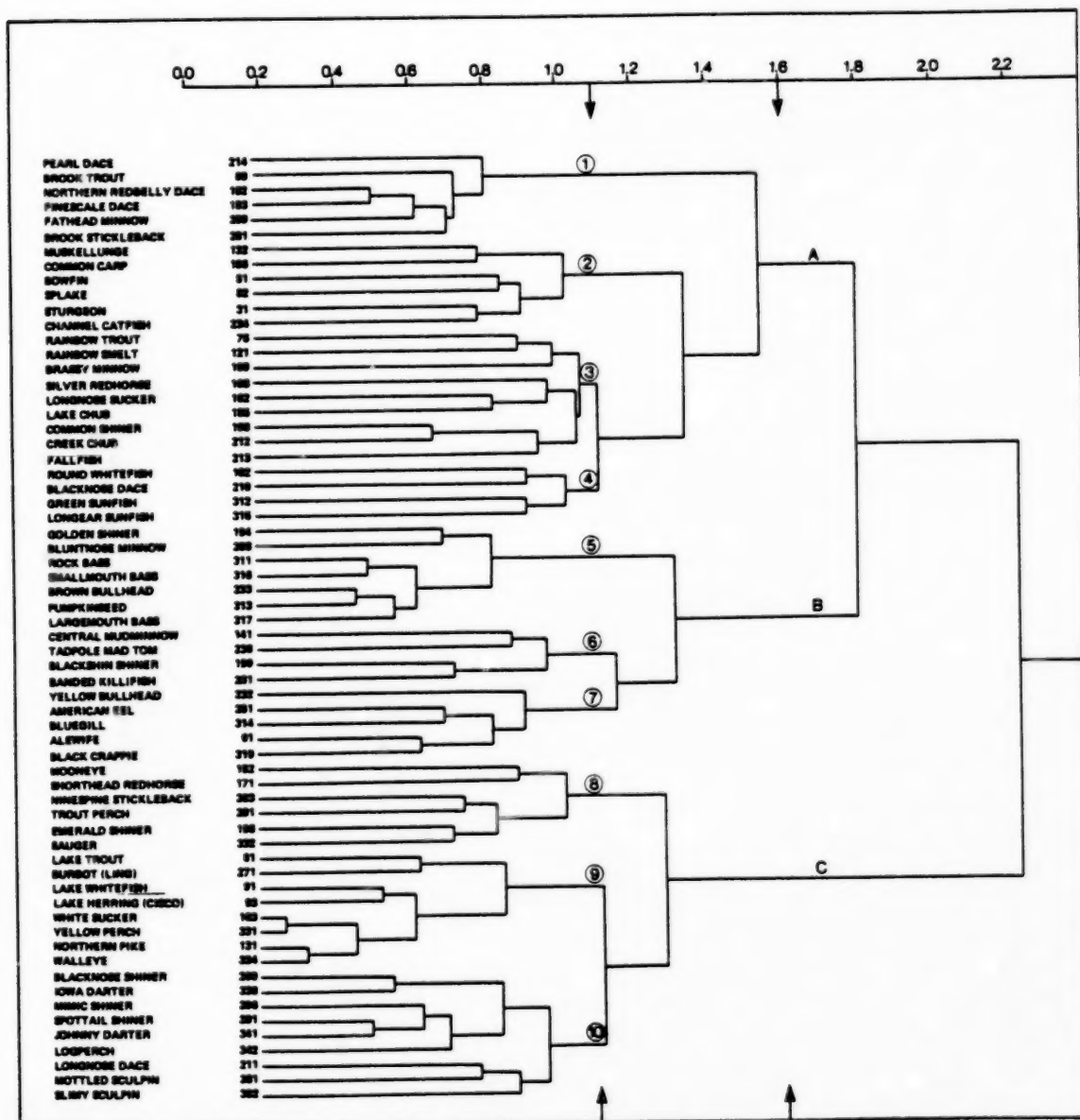


Figure 1. Fish species association dendrogram using Ochiai's index of association and hierarchical clustering with Ward's error sum-of-squares grouping rule.

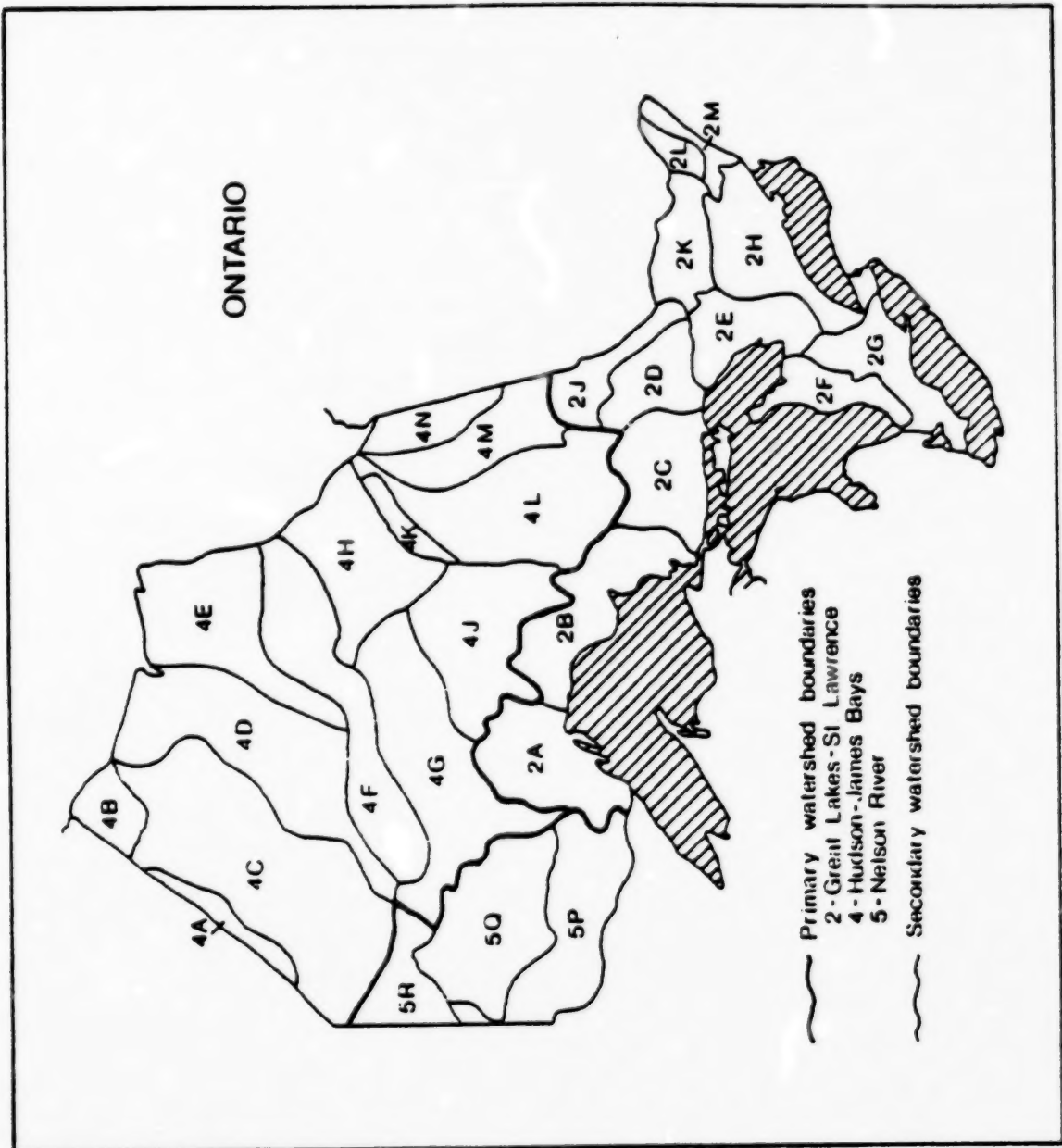


Figure 2. A map of Ontario showing the primary and secondary watershed boundaries.

APPENDIX A: LIST OF FISH SPECIES CONSIDERED IN THE ASSOCIATION ANALYSIS.

Common name	Scientific name	OMNR Code	Frequency of occurrence
Sturgeon	<u>Acipenser fulvescens</u>	31	45
Bowfin	<u>Ambloplites calva</u>	51	42
Alewife	<u>Alosa pseudoharengus</u>	61	28
Rainbow Trout	<u>Salmo gairdneri</u>	76	269
Brook Trout	<u>Salvelinus fontinalis</u>	80	1,764
Lake Trout	<u>Salvelinus namaycush</u>	81	1,634
Splake	<u>Hybrid</u>	82	38
Lake Whitefish	<u>Coregonus clupeaformis</u>	91	1,835
Lake Herring	<u>Coregonus artedii</u>	93	1,874
Round Whitefish	<u>Prosopium cylindraceum</u>	102	47
Rainbow Smelt	<u>Osmerus mordax</u>	121	130
Northern Pike	<u>Esox lucius</u>	131	3,875
Muskellunge	<u>Esox masquinongy</u>	132	180
Central Mudminnow	<u>Umbra lima</u>	141	154
Mooneye	<u>Hiodon tergisus</u>	152	21
Longnose Sucker	<u>Catostomus catostomus</u>	162	464
White Sucker	<u>Catostomus commersoni</u>	163	5,952
Silver Redhorse	<u>Moxostoma anisurum</u>	168	44
Shorthead Redhorse	<u>Moxostoma macrolepidotum</u>	171	268
Northern Redbelly Dace	<u>Phoxinus eos</u>	182	1,585
Pinescale Dace	<u>Phoxinus neogaeus</u>	183	746
Lake Chub	<u>Cuculus plumbeus</u>	185	552
Common Carp	<u>Cyprinus carpio</u>	186	79
Brassy Minnow	<u>Hybognathus hankinsoni</u>	189	64
Golden Shiner	<u>Notemigonus crysoleucas</u>	194	1,073
Emerald Shiner	<u>Notropis atherinoides</u>	196	214
Common Shiner	<u>Notropis cornutus</u>	198	997
Blackchin Shiner	<u>Notropis heterodon</u>	199	155
Blacknose Shiner	<u>Notropis heterolepis</u>	200	1,500
Spottail Shiner	<u>Notropis hudsonius</u>	201	1,447
Mimic Shiner	<u>Notropis volucellus</u>	206	563
Bluntnose Minnow	<u>Pimephales notatus</u>	208	984
Fathead Minnow	<u>Pimephales promelas</u>	209	1,291
Blacknose Dace	<u>Rhinichthys atratulus</u>	210	89
Longnose Dace	<u>Rhinichthys cataractae</u>	211	255
Creek Chub	<u>Semotilus atromaculatus</u>	212	870
Fallfish	<u>Semotilus corporalis</u>	213	92
Pearl Dace	<u>Semotilus margarita</u>	214	879
Yellow Bullhead	<u>Ictalurus natalis</u>	232	41
Brown Bullhead	<u>Ictalurus nebulosus</u>	233	1,148
Channel Catfish	<u>Ictalurus punctatus</u>	234	29
Tadpole Madtom	<u>Noturus gyrinus</u>	236	51
American Eel	<u>Anguilla rostrata</u>	251	41
Banded Killifish	<u>Fundulus diaphanus</u>	261	110
Burbot	<u>Lota lota</u>	271	1,270
Brook Stickleback	<u>Culaea inconstans</u>	281	1,007
Ninespine Stickleback	<u>Pungitius pungitius</u>	283	381
Trout-perch	<u>Percopsis omiscomaycus</u>	291	423
Rock Bass	<u>Ambloplites rupestris</u>	311	1,286
Green Sunfish	<u>Lepomis cyanellus</u>	312	23
Pumpkinseed	<u>Lepomis gibbosus</u>	313	1,840
Bluegill	<u>Lepomis macrochirus</u>	314	237
Longear Sunfish	<u>Lepomis megalotis</u>	315	50
Smallmouth Bass	<u>Micropterus dolomieu</u>	316	1,603
Largemouth Bass	<u>Micropterus salmoides</u>	317	722
Black Crappie	<u>Pomoxis nigromaculatus</u>	319	97
Yellow Perch	<u>Perca flavescens</u>	331	5,236
Sauger	<u>Stizostedion canadense</u>	332	125
Walleye	<u>Stizostedion vitreum vitreum</u>	334	2,340
Iowa Darter	<u>Etheostoma exile</u>	338	1,447
Johnny Darter	<u>Etheostoma nigrum</u>	341	991
Logperch	<u>Percina caprodes</u>	342	534
Mottled Sculpin	<u>Cottus bairdi</u>	381	413
Slimy Sculpin	<u>Cottus cognatus</u>	382	180